Arizona Geology

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THE STATE AGENCY FOR GEOLOGIC INFORMATION

MISSION

To inform and advise the public about the geologic character of Arizona in order to increase understanding and encourage prudent development of the State's land, water, mineral, and energy resources.

ACTIVITIES

PUBLIC INFORMATION

Inform the public by answering inquiries, preparing and selling maps and reports, maintaining a library, databases, and a website, giving talks, and leading fieldtrips.

GEOLOGIC MAPPING

Map and describe the origin and character of rock units and their weathering products.

HAZARDS AND LIMITATIONS

Investigate geologic hazards and limitations such as earthquakes, land subsidence, flooding, and rock solution that may affect the health and welfare of the public or impact land and resource management.

ENERGY AND MINERAL RESOURCES

Describe the origin, distribution, and character of metallic, nonmetallic, and energy resources and identify areas that have potential for future discoveries.

OIL AND GAS CONSERVATION COMMISSION

Assist in carrying out the rules, orders, and policies established by the Commission, which regulates the drilling for and production of oil, gas, helium, carbon dioxide, and geothermal resources.

TWENTY-SIX YEARS

Larry D. Fellows
Director and State Geologist
Arizona Geological Survey

It doesn't seem possible – twenty-six years ago, in February 1979, I became Arizona's state geologist! In the following paragraphs I've summarized some of the changes that have taken place since, and identified some of the individuals who helped make the changes possible. Many others, whose names are not listed, also provided valued assistance, support, and encouragement.

Setting the stage. "Oh, by the way, you're also the state geologist!" That's what Dr. William H. Dresher, a metallurgical engineer, was told in 1971, soon after he arrived in Tucson to begin serving as Dean of the College of Mines and Director of the Arizona Bureau of Mines (ABM) at the University of Arizona. His reply: "What's that?"

In 1915, three years after Statehood, the legislature established the ABM to carry out activities previously done by the Office of the Territorial Geologist and the metallurgical testing laboratory in the University School of Mines. The ABM functioned informally as the state geological survey, even though "state geological survey" and "state geologist" were not codified in the State of Arizona. The University administered the ABM as a department within the College of Mines.

Dr. Dresher took his responsibilities as ABM director and "state geologist" seriously, represented Arizona as a member of the Association of American State Geologists, learned about organization and functions of other state geological surveys, initiated efforts to modernize the ABM, and wrote a draft bill and successfully lobbied for its passage in 1977. Governor Raul H. Castro signed the bill, House Bill 2060, which created the "Arizona Bureau of Geology and Mineral Technology" to be administered as a division of the University of Arizona. The new bureau included a geological survey branch and a mineral technology branch and specified that the assistant director responsible for the geological survey branch shall be a registered geologist, qualified by education and experience, and carry the title "state geologist."

I was hired to be Arizona's first "official" state geologist. Before that, I was Assistant State Geologist at the Missouri Geological Survey (MGS) for seven years and a section chief, also at the MGS, for seven years before that. The experience gained in state geological survey administration in Missouri, under the direction of Dr. Wallace B. Howe, proved to be extremely useful.

Mapping and investigations. In Arizona I received invaluable support from Drs. Dresher and H. Wesley Peirce, Principal Geologist and 24-year employee. Wes introduced me to Arizona geology and passed on much more of his vast knowledge than my "Midcontinent" mind could absorb! We had many productive discussions about goals, projects, and priorities.

The Geological Survey Branch program soon began to gel, with priority given to the following activities: preparing detailed geologic maps, characterizing geologic materials and hazards, and providing objective geologic information to the public. When the legislature formulated the strategic planning process in the 1990s, these activities became agency goals.

Dr. Stephen J. Reynolds, who began employment in 1981, and Dr. Jon E. Spencer, hired in 1982, both had expertise in geologic mapping and structural geology and became the nucleus of the program. In 1983, when the U.S. Geological Survey initiated the Cooperative Geologic Mapping Program (COGEOMAP), the Geological Survey Branch was ready to participate. Dr. Philip A.

Pearthree was hired in 1988 to map and investigate surficial geology and geologic hazards. Steve Reynolds, after spending 10 productive years with the agency, resigned in 1991 to take a position at Arizona State University. Dr. Stephen M. Richard replaced him in 1992 to focus on mapping and mineral resource investigations. Since then, Richard has developed expertise in digital geologic mapping and database design and development as well. Geologists Tim Orr and Erin Moore helped advance the production of color maps and database products.

The National Geologic Mapping Act of 1992, which includes a component for funding state geological surveys, superseded COGEOMAP. The U.S. Geological Survey administers the mapping program. This has been the most productive and successful cooperative federal program in which the Arizona Geological Survey has participated. To date, the agency, one of the smallest state geological surveys, has been awarded $1,998,000 from the program, provided an equal match of State funds, and completed 145 geologic maps. Arizona ranks third in total funding awarded to the 48 state geological surveys that have participated. This is a testimonial to the strength of the mapping team – their ability to write successful funding proposals, prepare high quality maps in areas with complex geology, and complete the maps on time and within budget. The geologic mapping advisory committee (described in more detail under "advisory committees" below) determined mapping priorities.

New direction. With strong support from State Senator Doug Todd, Dr. Troy L. Péwé, and many other practicing geologists, the legislature passed Senate Bill 1102 in 1987. Governor Evan Mecham signed the bill, which transformed the Geological Survey Branch of the Bureau of Geology and Mineral Technology into the Arizona Geological Survey (AZGS), a stand-alone state agency, effective July 1, 1988. The purpose of the bill was to give the AZGS more visibility and accountability, make it more accessible and responsive to the public, and place it in an administrative setting in which it could more effectively function as a state agency. Governor Rose Mofford appointed me to be the first Director and State Geologist and the Arizona Senate confirmed the appointment (Figure 1).

Figure 1. Governor Rose Mofford appointed Larry D. Fellows as State Geologist in 1989.

Sunset reviews. When the Arizona Bureau of Geology and Mineral Technology was established a 15-year "sunset review" was scheduled for 1992. In 1985, at the midpoint of the review period, I asked Ralph Weeks, President of the Arizona Section of the American Institute of Professional Geologists (AIPG), to appoint a committee to review the performance of the Geological Survey Branch to ensure that the agency and would be ready for the sunset review. Ralph chaired the committee and asked Ken Euge, Walter Heinrichs, Dale Nations, and Frank Turek to serve with him. The committee pointed out several deficiencies, which the AZGS immediately began to correct. The AZGS completed the sunset review (Figure 2) and was extended for ten more years.

In 1997, at the midpoint of the second sunset-review period, I asked Dawn Garcia, President of the Arizona Section of the AIPG, to appoint a committee to review AZGS progress. Dawn chaired the committee and asked Alan Coope, Walter Heinrichs (who also served on the first review committee), and Erick Weiland to serve with her (Figure 3). Review procedures followed were similar to those used by a committee on which Alan Coope served to complete three reviews of the Geological Survey of Canada. The 60-page committee report, released as Open-File Report 97-20, included 29 conclusions and 26 recommendations that guide AZGS activities to this day. The AZGS, with guidance from this report, successfully completed its second sunset review in 2002.

Advisory committees. Geologic data users must have a strong voice in determining what "their" state geological survey does and how well it performs. If the agency doesn't provide maps, reports, and other information needed by practicing geologists and the public, it is wasting their hard-earned tax dollars. Shortly after the AZGS was established in 1988, I appointed three advisory committees to identify and prioritize activities that produce the information our customers need.

Environmental and Engineering Geology Advisory Committee members (Ken Euge, George Kiersch, Bruce Mack, Barbara Murphy, Steve Noel, Troy Péwé, Frank Turek, Ralph Weeks, Gary Weesner, and Bill Wellendorf) represented a broad spectrum of the geological community, including hydrogeology, engineering geology, mineral exploration, and education.

The committee concluded that investigating problems that have the greatest potential to impact the health, safety, and quality of life of Arizona's residents and that would require costly mitigation should be a primary AZGS objective. The committee report, which included five recommendations, was published in *Arizona Geology* (1990, v. 20, no. 4, p. 11).

Mineral Resources Advisory Committee members (Dan Aiken, Jim Briscoe, Russ Corn, Ted Eyde, John Forrester, Walter Heinrichs, Bob Hockett, Jim Loghry, Jim Mayor, Bob Metz, Charlie Miller, Jim Sell, and Pete Tillman) were senior geologists employed by mineral exploration or mining companies or as consultants. Committee members had a combined total of more than 400 years of exploration experience.

Making regional and detailed geologic maps was first on the list of recommendations the committee made. Companies and consultants rely on these maps, which they interpret and use to plan mineral-exploration programs and identify exploration target areas. The second priority was to maintain a computerized geologic database and a comprehensive library. The committee report, which included six recommendations, was published in *Arizona Geology* (1991, v. 21, no. 1, p. 3-4).

Figure 2. In 1992, Governor Fife Symington signed Senate Bill 1055, which extended the operation of the Arizona Geological Survey for another 10 years. Those observing are (left to right) Larry D. Fellows, geologists James A. Briscoe, William G. Welledorf, and Frank S. Turek, and State Senator Doug Todd.

Members of the Earth Science Education Advisory Committee (Carlon Ami, Susan Bollin, Bonnie Briscoe, Suzanne Cash, Don Clay, Chris Cotter, Ray Grant, David Harbster, Peter Kresan, Mike Lang, Alan Morton, Dale Nations, Beth Nichols-Boyd, Tony Occhiuzzi, Joe Schrieber, Jeff Simpson, Ed Stump, Bob Thompson, and Roger Weller) were high school earth-science teachers and geology faculty from community colleges, Arizona State University, Northern Arizona University, and the University of Arizona. Committee members recommended that information about the status of earth science education in Arizona be collected and analyzed (*Arizona Geology*, 1990, v. 20, no. 3, p. 4-6). On the basis of this information, the committee prepared a position paper on earth-science education, obtained endorsements from 30 professional and other groups, and successfully worked to convince the Arizona Board of Regents to give earth science equal standing with chemistry, physics, and biology as a laboratory science (*Arizona Geology*, 1992, v. 22, no. 3, p. 8-9).

The National Geologic Mapping Act of 1992 required each state geological survey that requested funding to appoint an advisory committee to determine areas of the state that have the greatest need to be mapped to meet societal needs. The Arizona Geologic Mapping Advisory Committee, which meets annually, presently consists of Barbara Murphy, chair, Al Burch, Chuck Graf, Bill Greenslade, Nick Priznar, Frank Putman, Mike Rice, and Ralph Weeks.

Oil and Gas Conservation Commission. In 1991, because of revenue shortfall, the legislature directed the AZGS to provide administrative and staff support for the Arizona Oil and Gas Conservation Commission (OGCC), a six-member board with an office and four employees in Phoenix. The OGCC and one employee, Steven L. Rauzi, were transferred to the AZGS in Tucson and the Phoenix office was closed. The OGCC regulates the drilling for and production of oil, gas, helium, geothermal, and carbon dioxide resources. At the present time all oil production in Arizona is from the Navajo Reservation. Since 1991, 42 test holes have been drilled. Most of the drilling was in search of carbon dioxide and helium. Current drilling activity is focused on helium exploration and underground storage of natural gas.

Rauzi, Oil and Gas Administrator, assists the OGCC in carrying out its regulatory duties and conducts subsurface geologic and related investigations. Steve directed the microfilming of oil and gas files, digitized well locations, and completed reports on potential for oil and gas, carbon dioxide, helium, and salt in Arizona.

The Governor appoints five members of the OGCC; the sixth, the State Land Commissioner, is *ex officio.* Dr. J. Dale Nations, chairman, Robert L. Jones, Joseph J. Lane, Michele P. Negley, Robert L. Wagner, and Mark Winkleman, Land Commissioner, are the current OGCC members.

Office space. From 1978 to 1995 the AZGS occupied basement space on Park Avenue adjacent to the University campus. In June 1995, because of the efforts of fiscal analysts Leslie

Schwalbe (Governor's budget office) and Keith Brainard (Joint Legislative Budget Committee), the AZGS moved to more spacious, newly remodeled offices in the State of Arizona Regional Complex in downtown Tucson (Fig. 4). The new offices are on the north side of Congress Street one block east of Interstate Highway 10. Ample parking is provided for easy access to the building. The publication sales area and offices of AZGS employees are bright and functional. The geology library is larger and includes room for expansion. Library visitors can comfortably view maps, reports, and data files.

Computers and databases. In 1979 the agency did not own a computer. Now most daily functions of the AZGS are computer based. Steve Reynolds, who brought the Geological Survey Branch into the computer age, developed many computer applications and laid the foundation for a bibliographic database on Arizona geology (AZGEOBIB). Richard A. Trapp, who began employment in 1991, subdivided the state into geographic areas, keyworded the bibliographic citations by subject and geographic area, and expanded AZGEOBIB to include more than 13,000 citations. Each year the agency receives hundreds of requests for bibliographies.

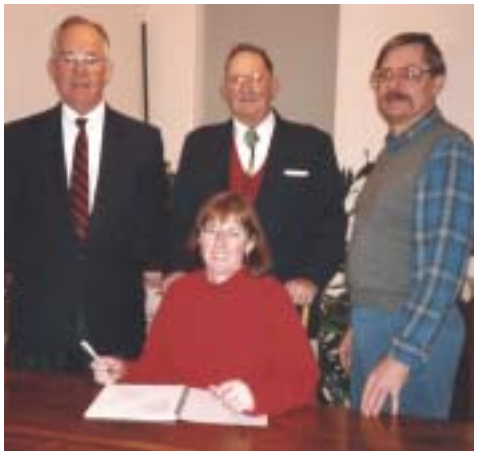

Figure 3. Members of an American Institute of Professional Geologists Committee completed a thorough review of the performance of the Arizona Geological Survey in 1997. Committee members are Dawn H. Garcia, chair (seated), and (standing, left to right) Alan Coope, Walter E. Heinrichs, and Eric F. Weiland.

The AZGS uses databases to catalog holdings in the library, oil and gas records, and various physical sample collections and to maintain inventories of maps and publications, personnel records, and mailing lists. Most AZGS publications are produced on premises using computers, GIS technology, and precision printers. Computers are now a fundamental tool of all agency employees.

Publications and sales. In the late 1970s and early 1980s the Geological Survey Branch released only formal publications (bulletins, circulars, special papers, and maps) that were printed commercially. The agency initiated the open-file report series in 1980, at the suggestion of Steve Reynolds. The purpose of that series is to make maps and reports of investigations available to the public in a timely manner without incurring the expense of printing them commercially. The contributed map and contributed report series, also printed on demand, were started later to include items that were prepared by geologists not employed by the AZGS. In 1993, in response to demand for digital information, the AZGS started the digital information series and, in 2000, the digital geologic map series. Steve Richard deserves most of the credit for starting the digital series.

The AZGS initiated the Down-to-Earth (DTE) publication series in 1991 to provide non-technical information to those who may have never taken a geology course. Prior to that, most AZGS publications and maps were technical and not easily understood by non-geologists. To date the AZGS has published 17 reports in the DTE series. Two (DTE 3: *Land Subsidence and Earth Fissures in Arizona* by Steven Slaff and DTE 13: *A Home-buyers Guide to Geologic Hazards in Arizona* by Raymond C. Harris and Philip A. Pearthree) have received the John C. Frye Award in Environmental Geology. This award is presented annually by the Geological Society of America and the Association of American State Geologists to the publication by either group that is judged to best describe the relationships between geology and environmental problems. John Bezy, a National Park Service geologist, collaborated with the AZGS to produce seven DTE books.

Since 1979 the AZGS published 61 maps and reports in the formal publication series (bulletins, circulars, maps, special papers, and down-to-earth) and released 426 in the open-file, digital information, and digital geologic map series. In addition, AZGS geologists submitted numerous articles for publication in outside professional journals and presented talks at many professional society meetings to summarize results of their studies.

The AZGS also released 133 reports and maps, prepared by geology graduate students and geologists not employed by the AZGS, in the miscellaneous map, contributed map, and contributed report series. One geologist, William L. Chenoweth, contributed 38 reports, largely about uranium occurrences and mining in northeastern Arizona. Bill, now retired, included information in these reports that was obtained while he worked for the U.S. Atomic Energy Commission and adapted the reports for release by the AZGS.

One objective of the AZGS is to serve as a "one-stop" shopping center for publications on Arizona geology. That goal was accomplished through cooperative agreements with the U.S. Geological Survey and the Arizona Geological Society in 1992. Publication sales have increased from less than $20,000 per year in the early 1980s to about $70,000 per year. Revenue from the sale of publications is deposited in a revolving fund and used to print and distribute publications.

Budget and staff. During the past 26 years, the AZGS has experienced budget and staff changes that impacted the operation of the agency (Table 1). Most years, the General Fund appropriation increased modestly due to inflationary increases until 2002 and 2003, when the State experienced revenue shortfall and severe budget cuts were made. The AZGS appropriation was reduced from $932,000 to $779,000, about 17 percent. Because of the high percentage of fixed costs that could not be reduced, however, a disproportionately high percentage of salaries had to be cut. Positions funded from the General Fund appropriation decreased from 12 to 8.5 (about 30 percent). These cuts have had a major negative impact on the operation of the AZGS. Just by chance, increased contract funds became available at the same time, and we were able to

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EXPENDITURES AND PRODUCTIVITY 1979-2004

ARIZONA GEOLOGICAL SURVEY

LARRY D. FELLOWS, DIRECTOR AND STATE GEOLOGIST

FISCAL YEAR	GENERAL FUND APPROPIATION (Avg/Yr $1,000)	CONTRACT EXPENDITURES (Avg/Yr $1,000)	TOTAL EXPENDITURES (Avg/Yr $1,000)	PERCENT NON-APPROPRIATED FUNDS	FULL TIME EMPLOYEES (General Fund)	MAPS & REPORTS SOLD (Avg/Yr $1,000)	MAPS & REPORTS PRODUCED (Avg/Yr)
1979-1983	225.2	NA	NA	NA	10.0	17.4	7.6
1984-1988	351.9	62.8	414.7	15.4	9.8	23.3	21.6
1989-1993	570.5	115.1	658.6	17.5	13.7	34.7	24.6
1994-1998	702.9	188.0	890.9	21.1	13.3	54.9	29.6
1999-2003	846.8	283.3	1,130.1	25.1	13.1	67.8	31.2
2004	*779.6*	*437.3*	*1,216.9*	*36.0*	*8.5*	*70.6*	*24.0*

Table 1

switch several state-funded employees to "soft" money so none had to be terminated. Efforts to restore these key positions to state funding have not been successful.

The AZGS routinely provides geologic information to all who request it. Occasionally an agency or group needs information that is not available. Under those circumstances, that agency may fund the AZGS to provide, under contract, the specific information it needs. Some cooperative projects require shared expenses through use of matching funds. By using contract funds the AZGS supplements the General Fund appropriation and completes more maps and studies than could otherwise be done. The dollar value of contracted projects, which varies from year to year, has steadily increased. Spending of contracted funds, calculated as a percentage of the total annual AZGS expenditure, has doubled since the 1980s.

Figure 4. In June 1995, Arizona Geological Survey staff moved into newly remodeled offices in downtown Tucson.

Turnover at the AZGS has been largely among publication sales staff and contracted employees. Thomas G. McGarvin is the only current staff member whose employment began before I arrived. Tom, who started working for the Arizona Bureau of Mines in 1972, maintains the geology library and is the primary information source for visitors with geologic questions, library users, and elementary and secondary science and earth science teachers.

Support staff perform duties necessary to keep the AZGS operating, such as budgeting, accounting, personnel, payroll, contract management, equipment purchase and maintenance, inventory, facility management, editing, graphics, and publication sales. Rose Ellen McDonnell, who began employment here in 1987, is Assistant Director of Administration. As such, she has oversight for administrative and support duties which have increased substantially. At the same time, the number of administrative and support staff has declined, due to of budget cuts and efficiency associated with computerization.

Conclusions. My service to the State of Arizona and Arizonans will end when I retire June 30. The 26-plus years I've directed the AZGS seem to have passed very quickly. It's gratifying to review the progress that has been made–progress that would not have been possible without the involvement, support, and/or encouragement provided by the following: AZGS staff, practicing and retired geologists, university faculty, earth science teachers, staff from the Office of the Governor, legislators and committee staff, fiscal analysts, staff from the office of the Attorney General, interested citizens, and friends. I've enjoyed the close working relationships with employees of the Departments of Environmental Quality, Transportation, and Water Resources, State Land Department, State Parks, and the Department of Library, Archives, and Public Records. I appreciate the support received and am grateful to all who contributed to the development and operation of the AZGS over the years.

Interacting with the directors and staff of other state geological surveys through activities of the Association of American State Geologists (AASG) was an informative, productive, and enjoyable part of my job. The privilege of serving as president of the AASG in 1989-90 was a highlight of my career.

Last, but certainly not least, I express appreciation to my wife, Jeanne, for her patience, understanding, and support that began long before we moved to Arizona.

PUBLICATION ORDERING INFORMATION

You may purchase publications at the AZGS office or by mail. Address mail orders to AZGS Publications, 416 W. Congress St., Suite 100, Tucson, AZ 85701. Orders are shipped by UPS, which requires a street address for delivery. All mail orders must be prepaid by a check or money order payable in U.S. dollars to the Arizona Geological Survey or by Master Card or VISA. Do not send cash. Add 7.6% sales tax to the publication cost for orders purchased or mailed in Arizona. Order by publication number and add these shipping and handling charges to your total order:

Shipping & Handling CHARGES

In the United States

Less than	$2.00,		add	$2.50
	2.01 -	10.00,	add	6.00
	10.01 -	20.00,	add	7.50
	20.01 -	30.00,	add	8.75
	30.01 -	40.00,	add	9.50
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	50.01 -	100.00,	add	13.00
	101.01 -	200.00,	add	17.00
More than	200.01 -			call

Other countries, request price quotation

Shipping and handling charges include insurance.
For rolled maps, add $1.00 for a mailing tube.

Mark Your Calender

September 24: Verde River Day, Cottonwood. Learn about and enjoy the Verde River at Dead Horse Ranch State Park. Entertainment, non-technical geology "walks." and other outdoor activities are provided.

January 12-15, 2006: Wings Over Willcox, Willcox. Birding, geology, mining, archaeology, ranching, and other field trips, seminars, and related events are held. Geology trips are taken to Fort Bowie, Chiricahua National Monument, and the Willcox Playa. Advance registration for trips is suggested.

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